Imperial College London

National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

NPL National Physical Laboratory

Science at Imperial College in support of the FORUM mission

Laura Warwick,
Helen Brindley, Jon Murray, Richard Bantges, Alessio Di Roma, Stuart Fox, the team from the FAAM Airborne Laboratory and many others!

Outline

- Aircraft measurements and the FAAM Airborne Laboratory
- Recent Science
  - Ice Clouds
  - Water vapour
  - Surface emissivity
- Future developments

Instrumentation

Aircraft instruments
Position
Altitude
Water vapour
Temperature
Ozone
etc.

TAFTS
FIR spectrometer
80 – 550 cm^{-1}

ARIES
MIR spectrometer
600 – 3000 cm^{-1}

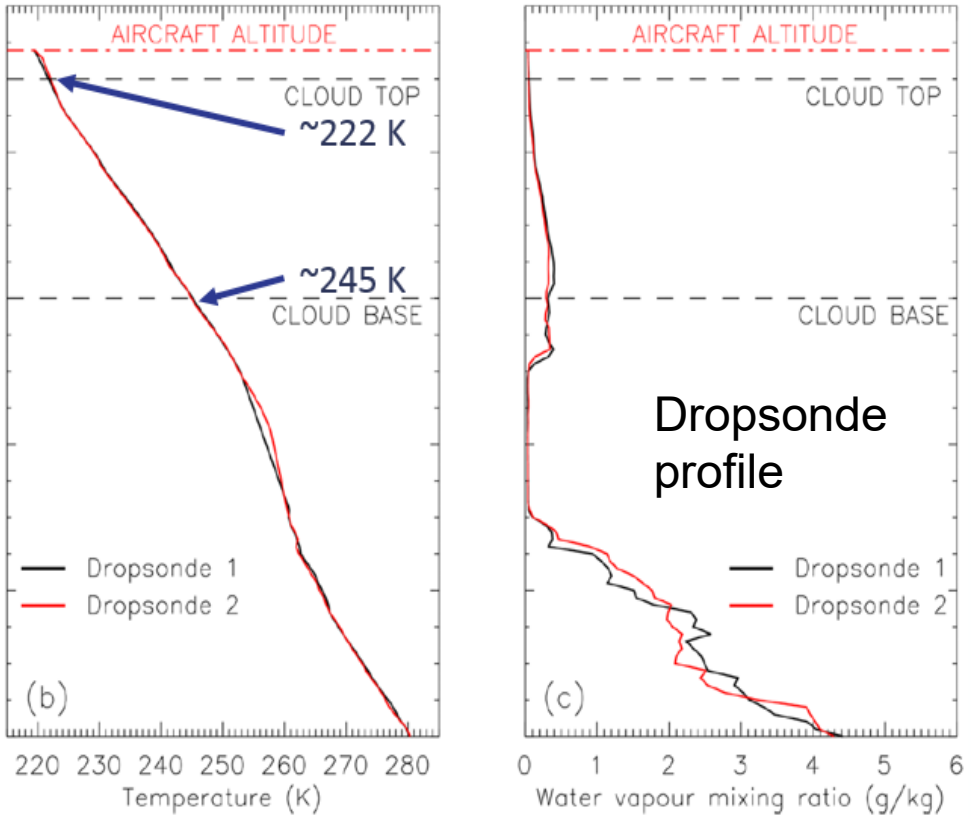
Dropsonde
Temperature
Water vapour
Pressure

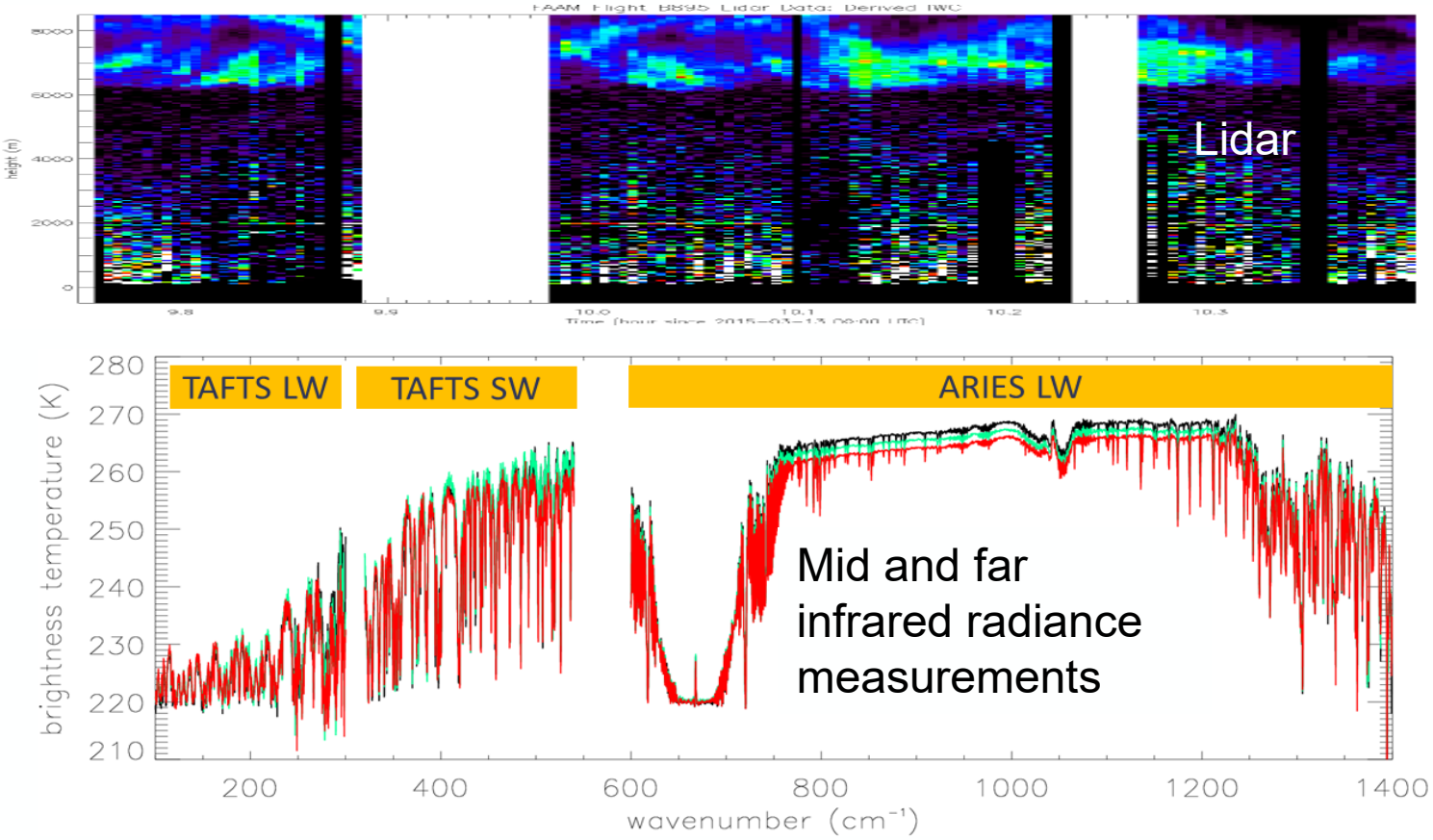
https://www.vaisala.com
Not to scale.

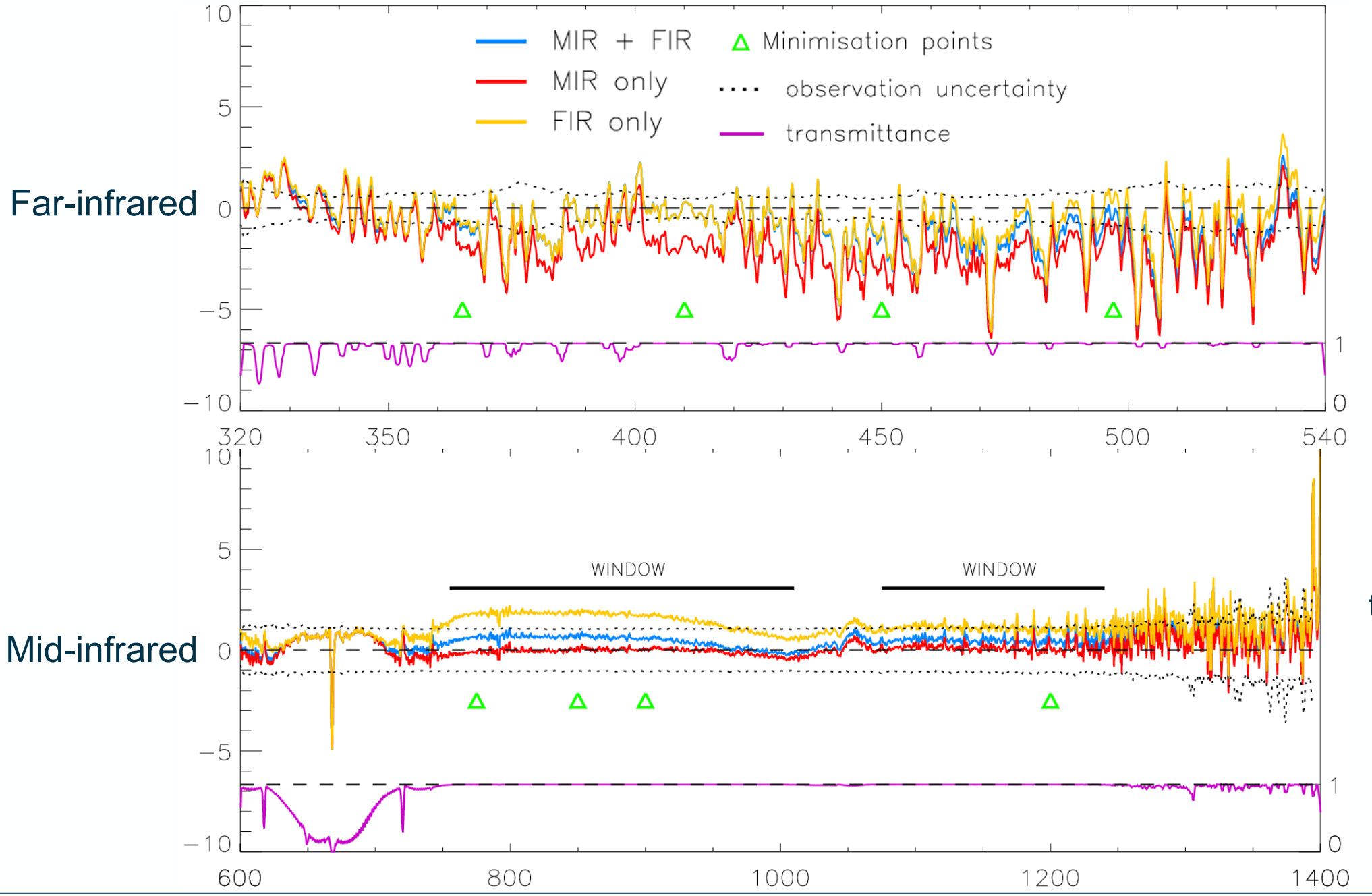
Do current ice cloud models perform well across the infrared?

Radiative Signature of Ice Clouds

- ~ 30 minutes of high-level observations (~9.4 km) overflying thin cirrus







Bantges et al., ACP, 2020

Ongoing work testing if a different approach to ice cloud modelling can reconcile this

Take home messages

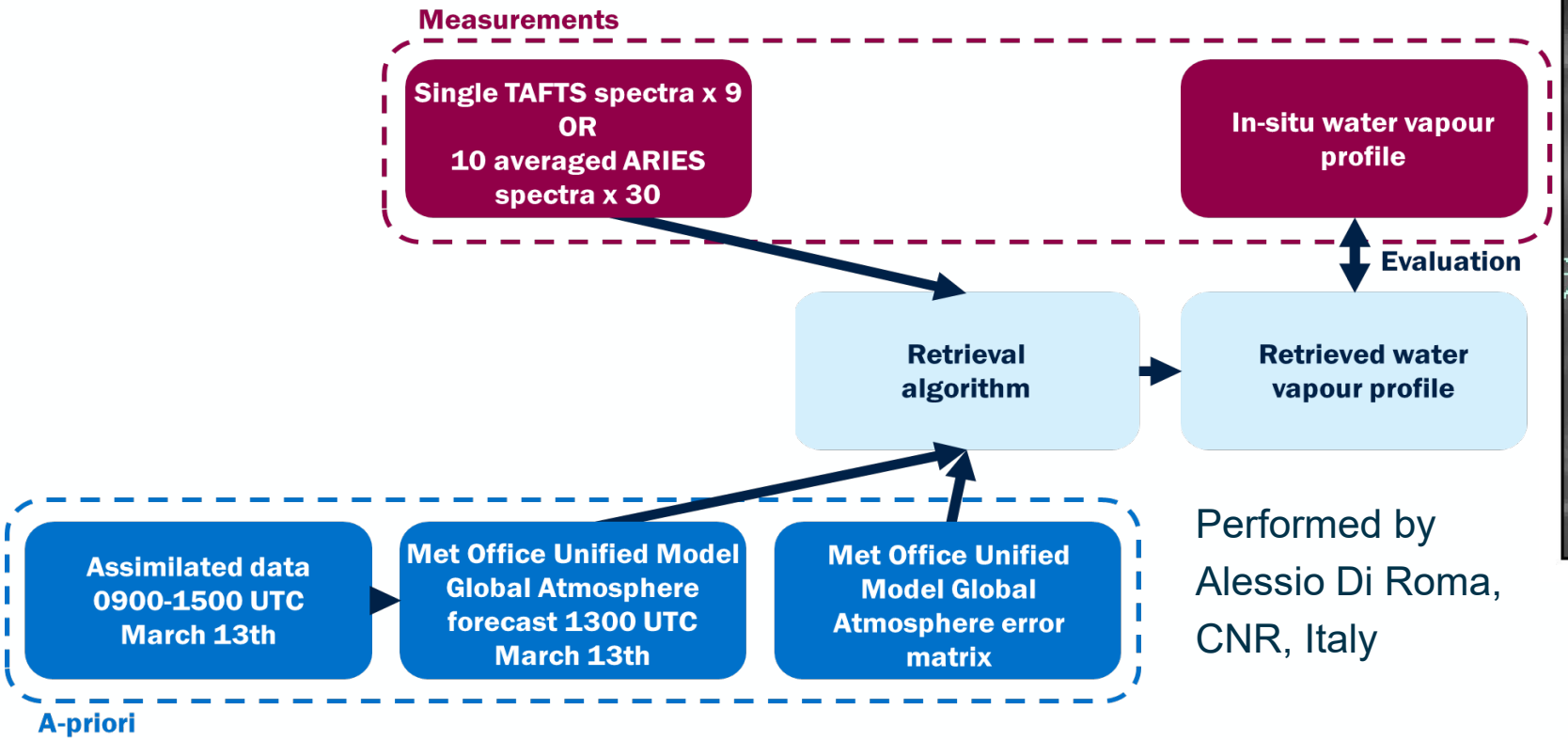
- The ice cloud model cannot match observations across the whole infrared spectrum

- FORUM will provide vital information about ice cloud radiative properties

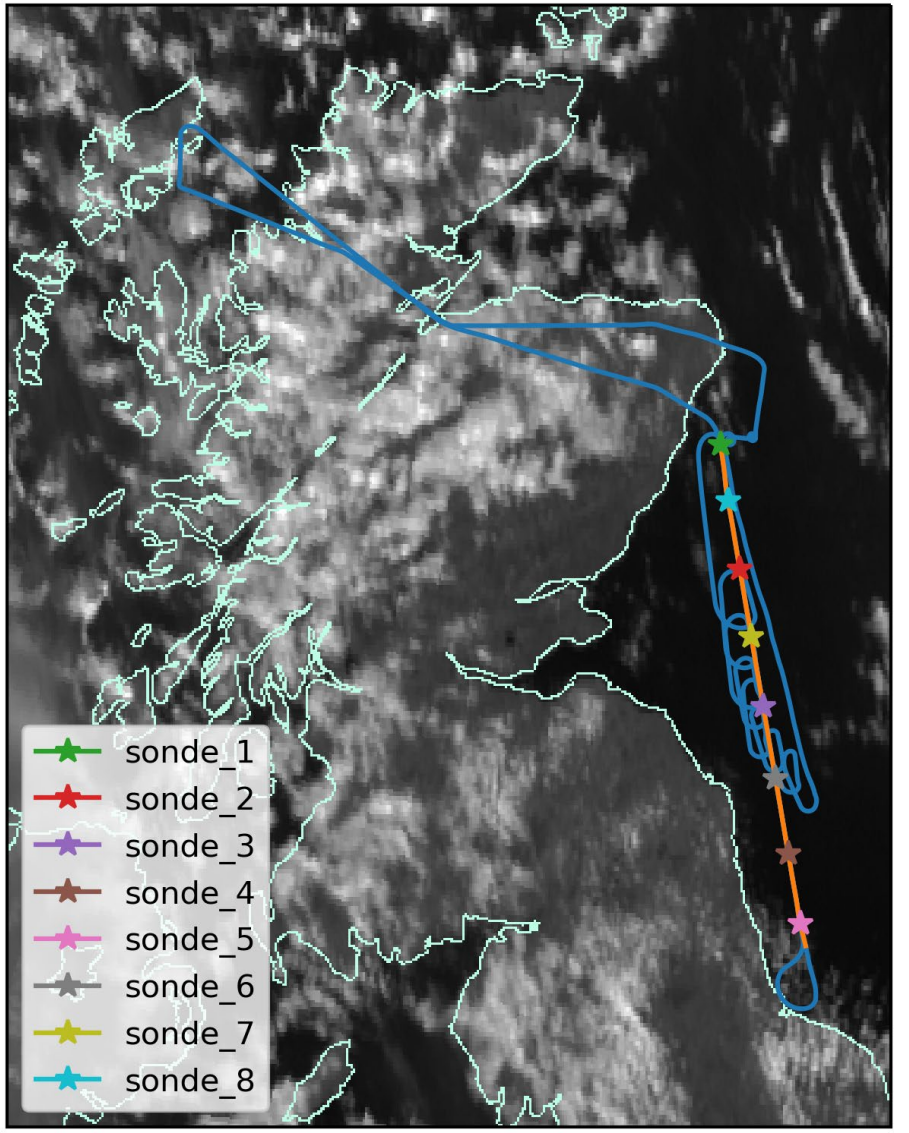
How well can we retrieve water vapour profiles using far-infrared radiances measured from aircraft?

Water Vapour Retrieval

- Clear sky high level (9 km) observations
- Water vapour retrievals performed using mid and far infrared radiances

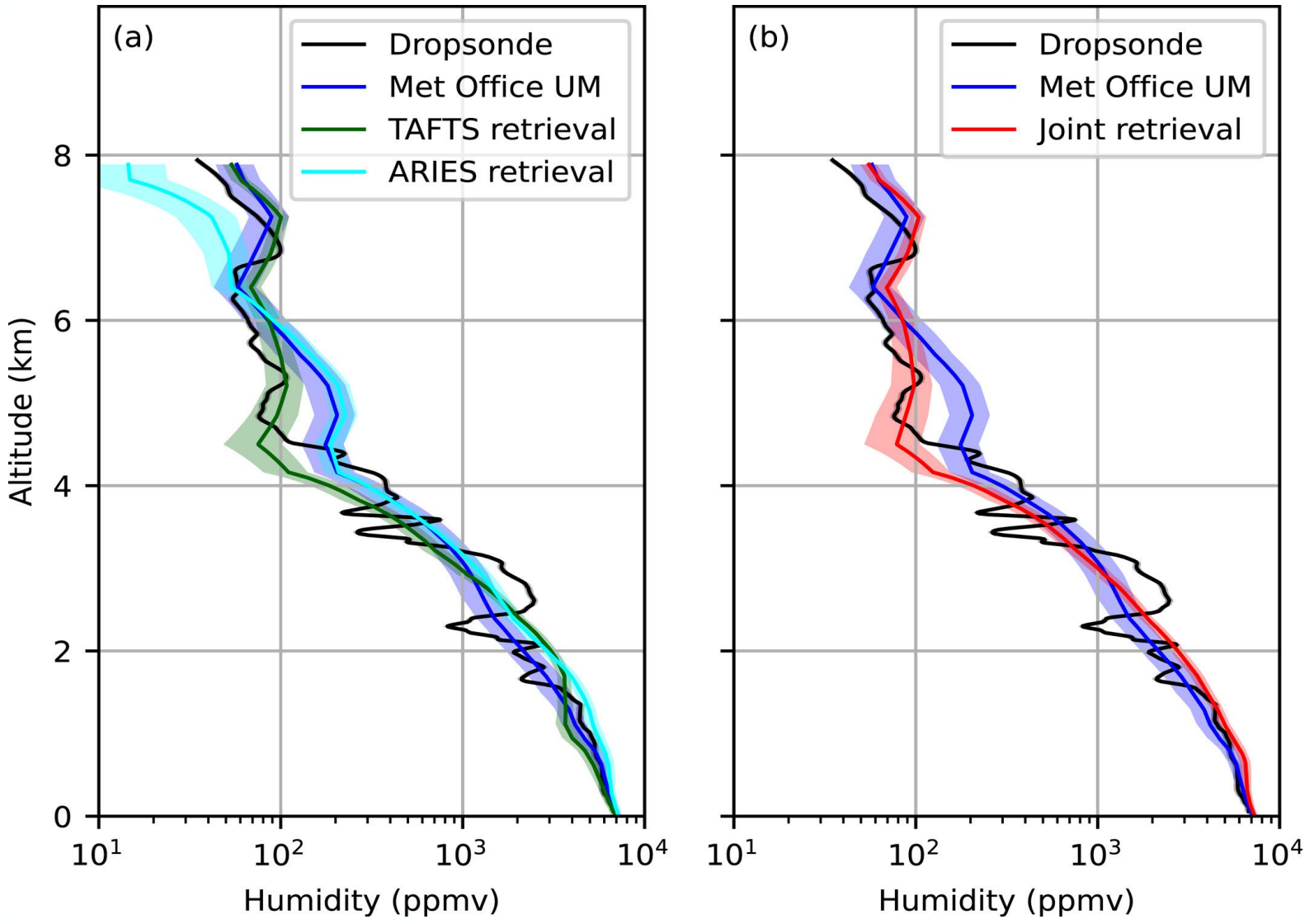


Performed by Alessio Di Roma, CNR, Italy



Flight track during C153 with high-resolution visible satellite image from MSG at 12:30UTC. Stuart Fox Met Office

Water Vapour Retrieval



Configuration	DFS
TAFTS only	6.46
ARIES only	3.55
TAFTS & ARIES	6.65

Far-infrared retrieval contains more water vapour information and is a better match for the dropsonde measurements

Warwick et al., JGR, 2022

Take home messages

- We expect the far-infrared advantage will be maintained for FORUM only measurements

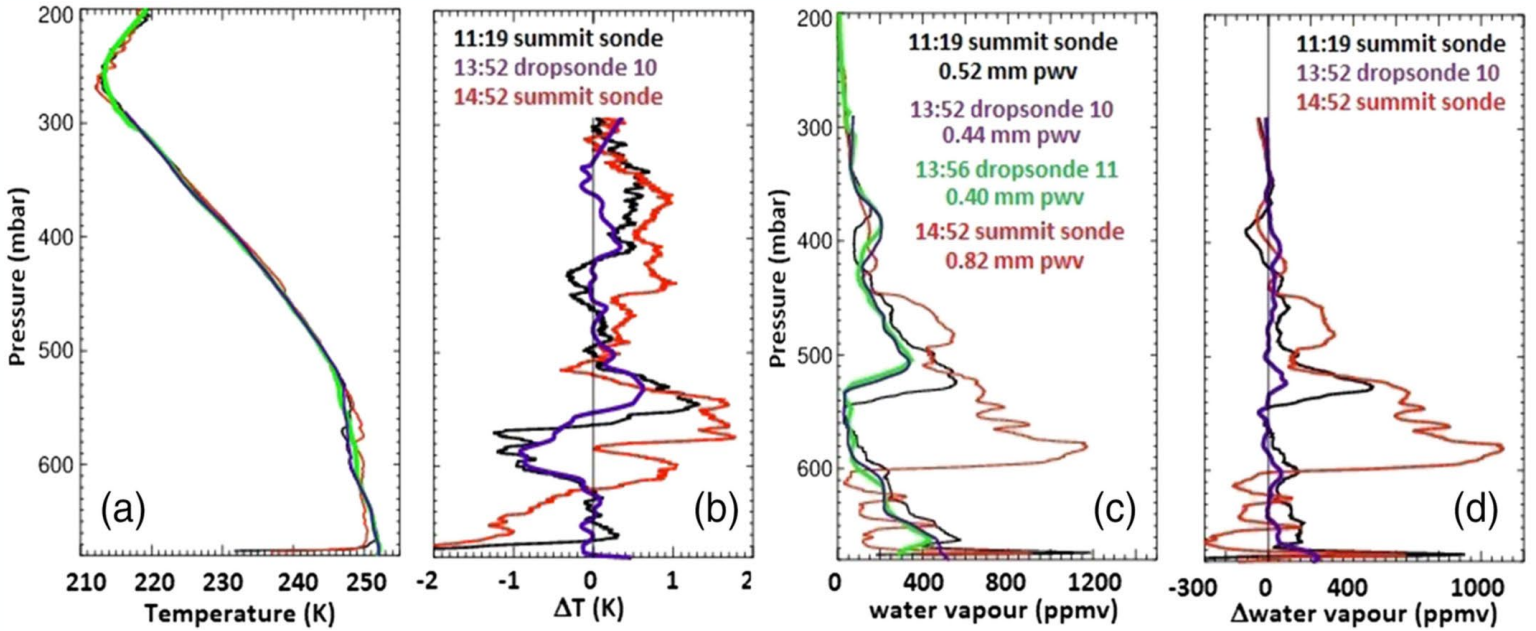
- For FORUM-IASI-NG combined measurements, the advantage is not expected to be as large (e.g. Ridolfi et al., 2020)

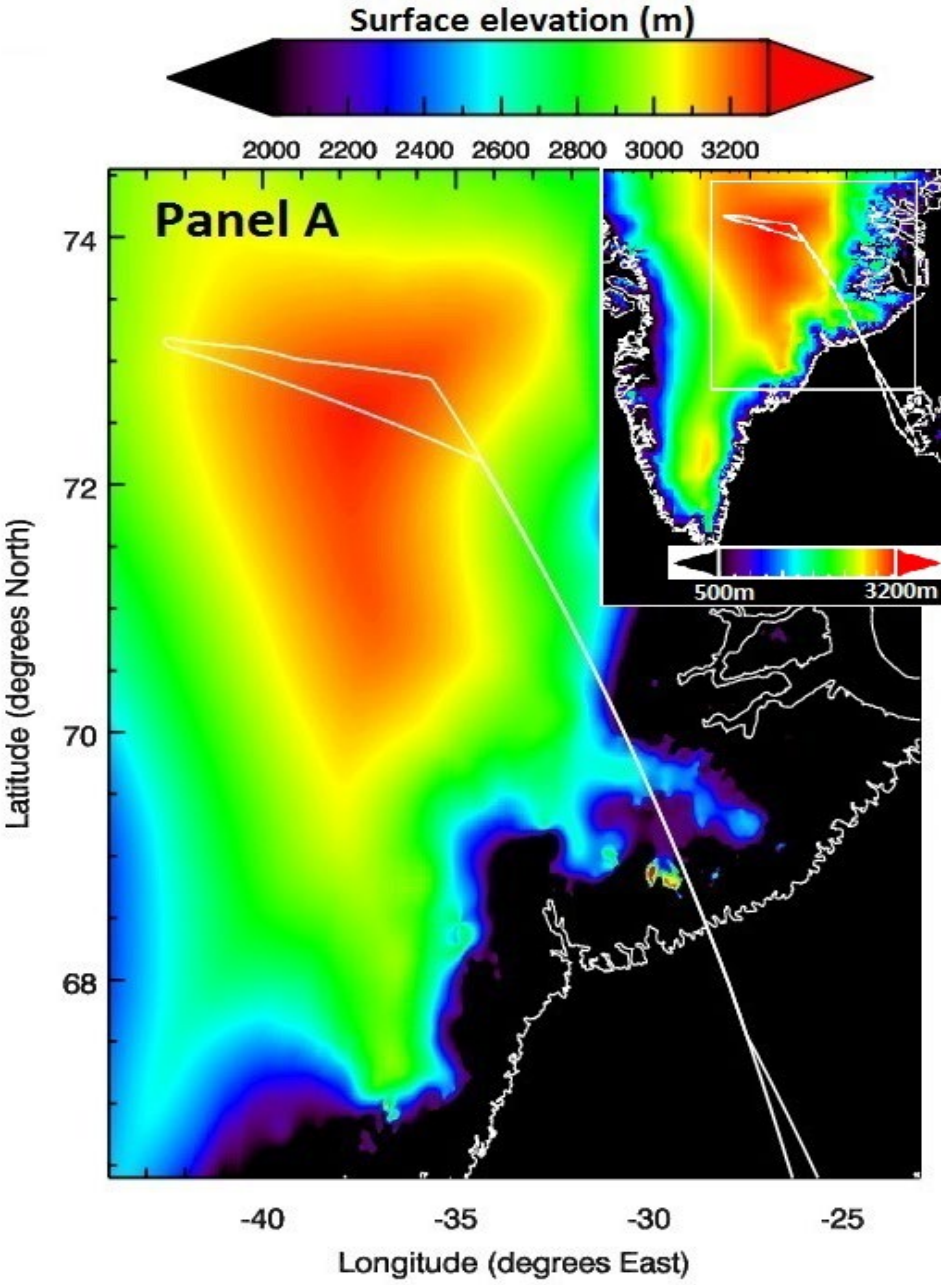
Can we retrieve far-infrared surface emissivity from altitude?

Surface emissivity measurement

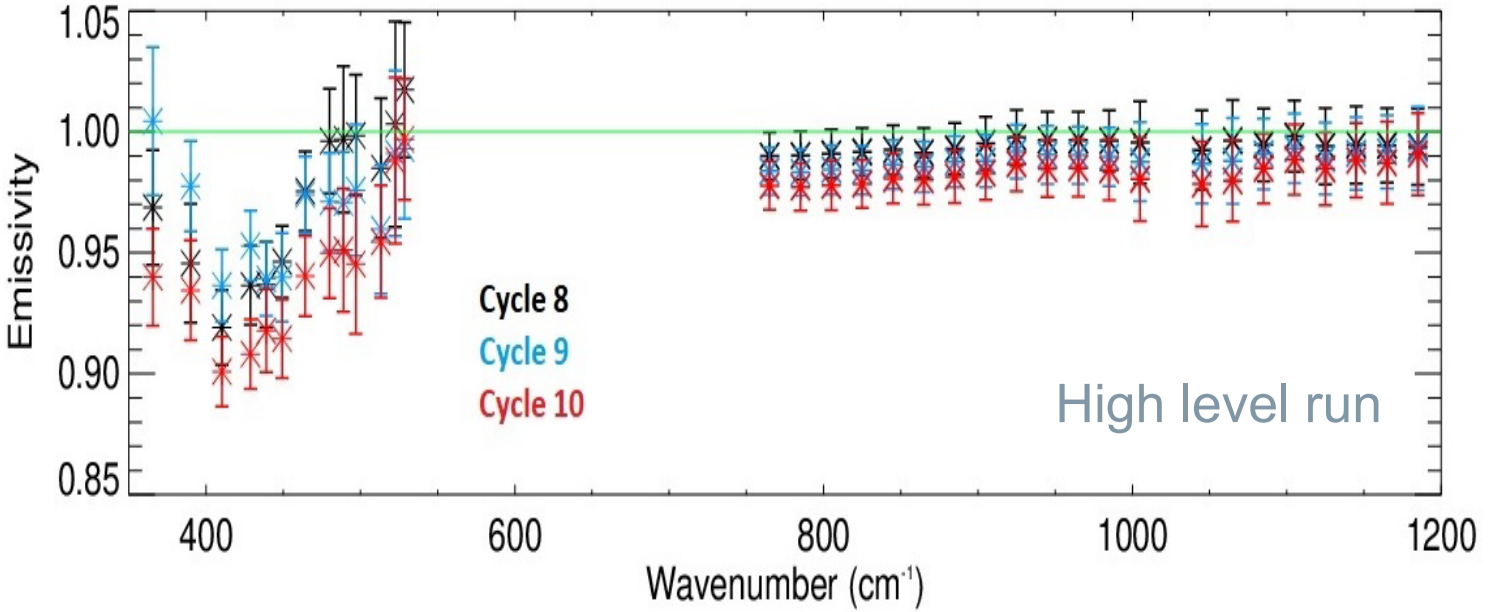
- Flight of opportunity over the Greenland ice sheet

Run	Time	Distance above ice	TCWV
High level	1400 UTC	6 km	0.4 mm
Low level	1452 UTC	330 m	0.08 mm

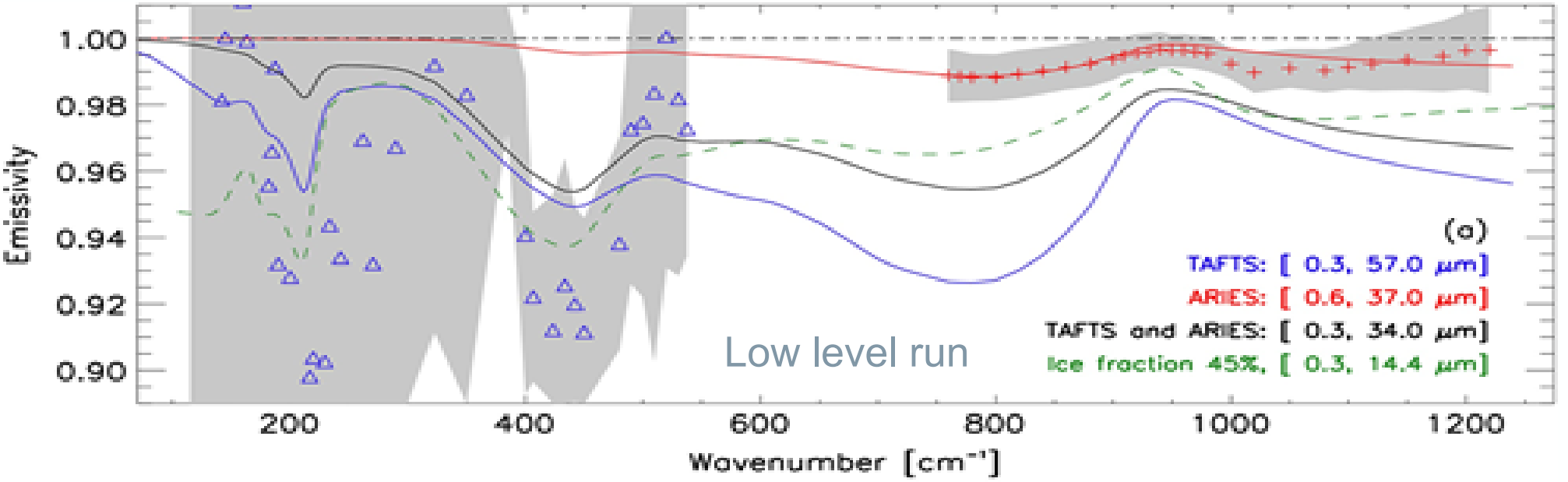




Murray et al., JGR, 2020



Bellisario et al., JGR, 2017



Emissivity significantly < 1 at n < 500 cm^{-1}

High and low altitude retrievals agree within uncertainties

Even small amounts of water vapour preclude retrievals at smallest wns

Take home messages

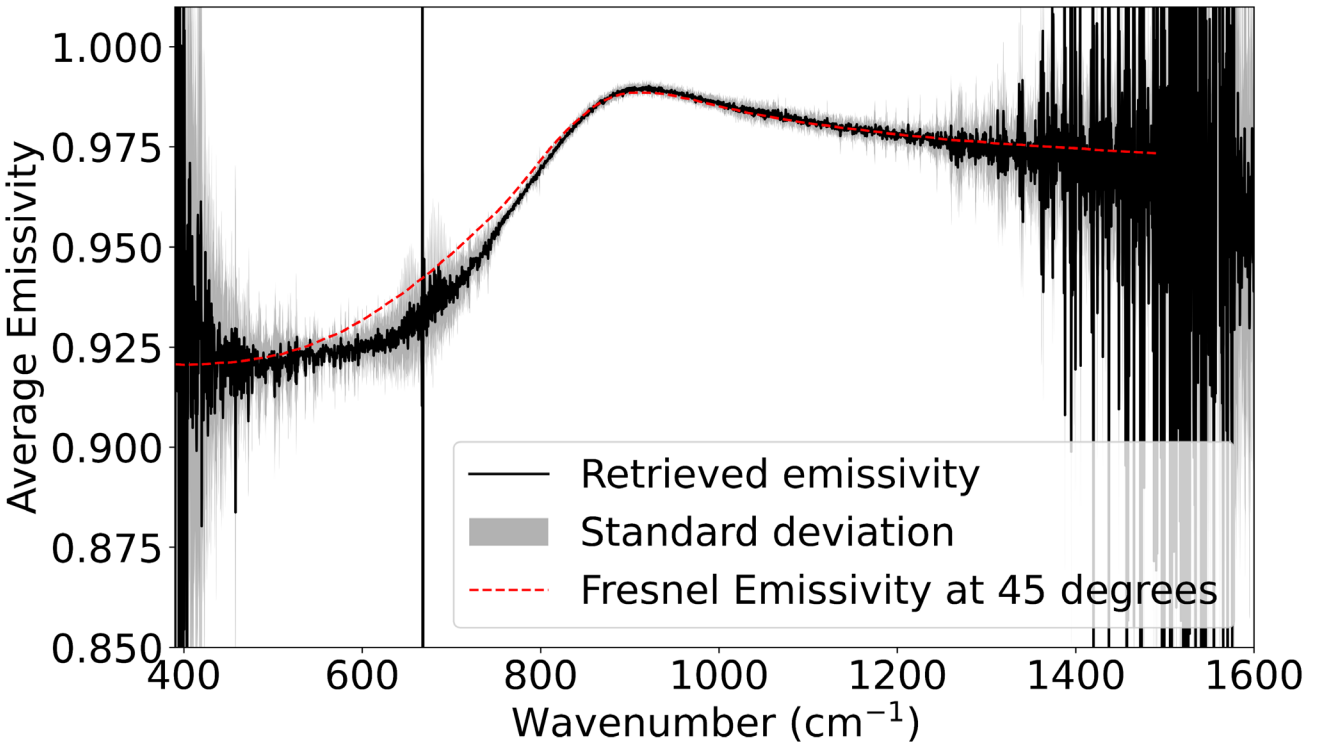
- It is possible to measure far-infrared surface emissivity from altitude

- Ice emissivity is significantly below 1 at wavenumbers less then 500 cm^{-1}

Future Developments at Imperial College

FINESSE: Far-INfrarEd Spectrometer for Surface Emissivity

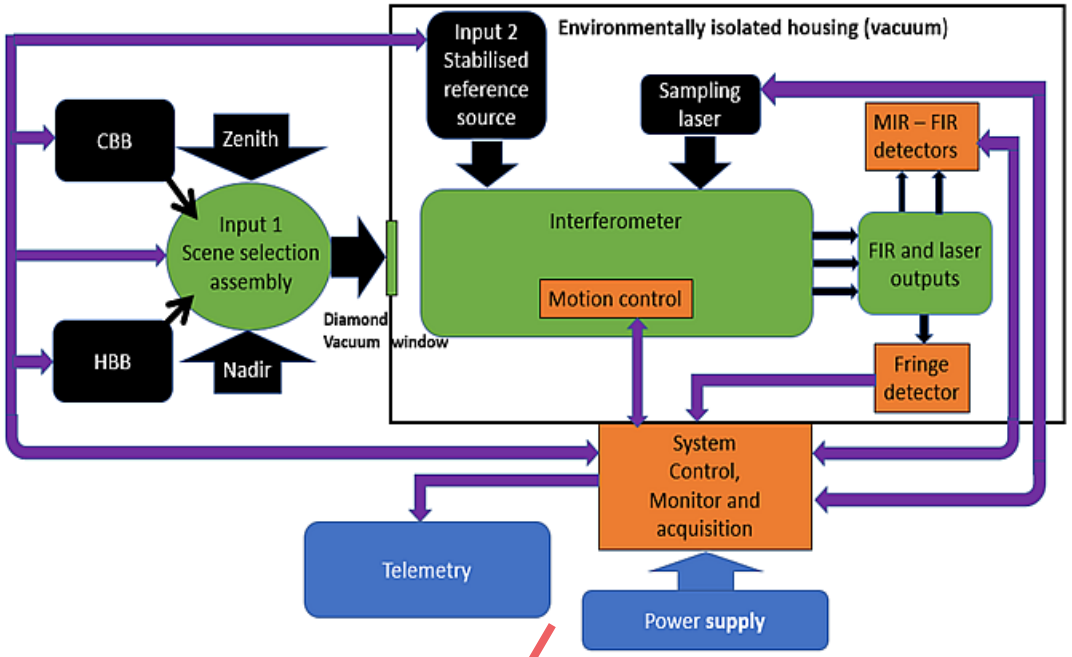
- FINESSE is intended to make in-situ measurements of surface emissivity
- For more information see poster 565



UNIRAS: UNiversal InfraRed Airborne Spectrometer

- 4-port airborne FTS with configurable detectors
- Project Kick-Off early June, goal to participate in CCREST campaign (March 2025) and serve as a FORUM cal/val facility

	FORUM-like	Extended MIR
Spectral range	100-1600 cm^{-1}	400-1600 cm^{-1}
Spectral resolution	0.5 cm^{-1}	0.5 cm^{-1}
Footprint from 10 km at typical FAAM science speed	430 x 850 m	430 x 500 m
NESR when averaged over equivalent footprint	NESR <= FORUM threshold at wn < 500 cm^{-1} NESR << FORUM goal at wn > 500 cm^{-1}	

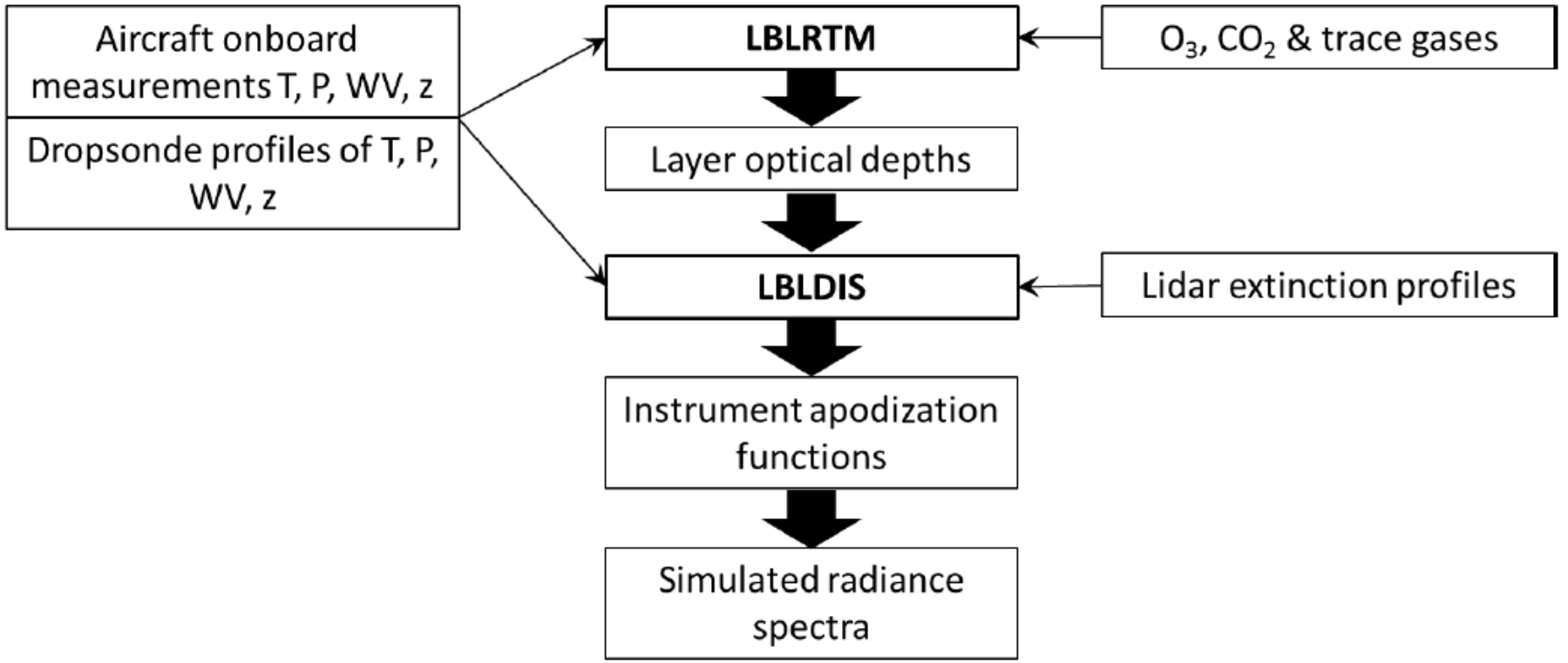


Summary and Future Outlook

- Using aircraft observations, we have shown how FORUM will provide far-infrared radiance measurements that can enhance our understanding of
  - Ice cloud properties
  - Atmospheric Water Vapour
  - Surface Emissivity
- The aircraft data underpinning these studies are available on the CEDA archive: https://archive.ceda.ac.uk/
- The FINESSE and UNIRAS instruments will enable us to continue making airborne and ground based far-infrared measurements

Radiative Signature of Ice Clouds

- Simulated spectra produced using bulk ice optical properties from Baum et al., 2014



Surface emissivity measurement

$$L^{\uparrow} = \underbrace{\varepsilon_s B(T_s)\tau}_{\text{Surface emission transmitted to plane}} + E^{\uparrow} + \underbrace{(1-\varepsilon_s)(L^{\downarrow}\tau^2 + E^{\downarrow}\tau)}_{\text{Downward atmospheric emission reflected by surface and transmitted back to plane}}$$

Upward emission from atmosphere below plane

$$\varepsilon_s = \frac{L^{\uparrow} - \tau^2 L^{\downarrow} - E^{\downarrow}\tau - E^{\uparrow}}{\tau B(T_s) - \tau^2 L^{\downarrow} - \tau E^{\downarrow}}$$

Green: TAFTS/ARIES observations
Blue: surface temperature retrieved from ARIES/Heimann
Red: atmospheric transmission and emission simulated by Line-by-Line Radiative Transfer Model (LBLRTM) using knowledge of atmospheric state